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☐ 1. Document ID: US 6054077 A

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L3: Entry 1 of 2 File: USPT Apr 25, 2000

US-PAT-NO: 6054077
DOCUMENT-IDENTIFIER: US 6054077 A

TITLE: Velocity profiling in an extrusion apparatus

DATE-ISSUED: April 25, 2000

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Comb; James W.	Hamel	MN		
Leavitt; Paul J	Minneapolis	MN		
Rapoport; Edward	Minneapolis	MN		

US-CL-CURRENT: 264/40.7; 425/145, 425/375, 425/376.1

Full | Title | Citation | Front | Review | Classification | Date | Reference | Claims | KWIC | Draw De

☐ 2. Document ID: US 6054077 A

L3: Entry 2 of 2 File: DWPI Apr 25, 2000

DERWENT-ACC-NO: 2000-374747
DERWENT-WEEK: 200032
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TITLE: Extrusion apparatus in prototyping systems for three-dimensional objects, controls extrusion head and filament drive so that extrusion head velocity is proportional to estimated profile of extruded pump flow rate

INVENTOR: COMB, J W; LEAVITT, P J ; RAPOPORT, E

PRIORITY-DATA: 1999US-0228095 (January 11, 1999)

PATENT-FAMILY:

PUB-NO	PUB-DATE	LANGUAGE	PAGES	MAIN-IPC
US 6054077 A	April 25, 2000		020	B29C041/02

INT-CL (IPC): B29 C 41/02; B29 C 41/52; B29 C 47/92

Full | Title | Citation | Front | Review | Classification | Date | Reference | Claims | KWIC | Draw. De

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(6054077.PN.).PGPB,USPT,EPAB,JPAB,DWPI.	2

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Previous Page Next Page Go to Doc#

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L6: Entry 1 of 2 File: USPT Apr 14, 1998

US-PAT-NO: 5738817
DOCUMENT-IDENTIFIER: US 5738817 A
** See image for Certificate of Correction **

TITLE: Solid freeform fabrication methods

DATE-ISSUED: April 14, 1998

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Danforth; Stephen C.	Belle Mead	NJ		
Agarwala; Mukesh	Highland Park	NJ		
Bandyopadghyay; Amit	Edison	NJ		
Langrana; Noshir	Robbinsville	NJ		
Jamalabad; Vikram R.	Somerville	NJ		
Safari; Ahmad	Princeton Junction	NJ		
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US-CL-CURRENT: 264/603; 264/255, 264/308, 264/604, 264/678, 419/1, 419/36, 419/5, 700/119

CLAIMS:

We claim:

1. A process for making a three-dimensional article, comprising the steps of:

providing a mixture of a particulate composition dispersed in a binder;

feeding said mixture to a dispensing apparatus;

dispensing said mixture from said dispensing apparatus onto a build platform;

during said dispensing step, moving said dispensing apparatus and said build platform relative to one another in a plane defined by first and second directions and in a third direction orthogonal to said plane to form said mixture into a three-dimensional article; and

removing at least a portion of said binder from said article.

2. A process as claimed in claim 1, further comprising the step of forming said mixture into a solid flexible filament prior to said feeding step.

3. A process as claimed in claim 2, wherein said feeding step includes the step of feeding said

filament to said dispensing apparatus in a solid state, and said dispensing step includes the step of heating said filament to place said mixture in a flowable fluid state.

4. A process as claimed in claim 2, further comprising the step of winding said filament around a spool prior to said feeding step, said filament being sufficiently flexible to uniformly wrap in a smooth curve around said spool and being sufficiently rigid to not be deformed by compressive forces during said feeding step.

5. A process as claimed in claim 1, wherein said particulate composition is selected from the group consisting of ceramic materials, elemental metals, steels, metal alloys and combinations thereof.

6. A process as claimed in claim 1, wherein said mixture includes at least about 10 volume percent of said particulate composition.

7. A process as claimed in claim 6, wherein said mixture includes at least about 40 volume percent of said particulate composition.

8. A process as claimed in claim 7, wherein said mixture includes at least about 50 volume percent of said particulate composition.

9. A process as claimed in claim 1, wherein said particulate composition includes between about 0.3 volume percent and about 19.0 volume percent of a dispersing agent.

10. A process as claimed in claim 9, wherein said dispersing agent is selected from the group consisting of oleyl alcohol (9-octadecen-1-ol), 3-aminopropyltriethoxysilane, and KRTTS (Titanium IV 2-propanolato tris (isooctadecanoato-o)).

11. A process as claimed in claim 1, wherein said binder is selected from the group consisting of thermoplastic binders, thermosetting binders, water soluble binders and organic solvent soluble binders.

12. A process as claimed in claim 1, wherein said mixture has an initial flowable fluid state and a solid state, said dispensing step including the steps of dispensing said mixture in said flowable fluid state and permitting said mixture to solidify on said build platform.

13. A process as claimed in claim 12, wherein said moving step includes the steps of moving said dispensing apparatus and said build platform relative to one another in a direction parallel to said plane to form a first layer of said mixture on said build platform, moving said dispensing apparatus and said build platform away from one another in said third direction by a predetermined layer thickness, and after the portion of said first layer adjacent said dispensing apparatus has solidified, dispensing a second layer of said mixture in said fluid state onto said first layer while simultaneously moving said build platform and said dispensing apparatus relative to one another in said direction parallel to said plane, whereby said second layer solidifies and adheres to said first layer.

14. A process as claimed in claim 13, further comprising the steps of forming multiple layers of said mixture on top of one another by repeated dispensing of said mixture in said fluid state from said dispensing apparatus as said build platform and said dispensing apparatus are moved relative to one another in said direction parallel to said plane, with said dispensing apparatus and said

build platform being moved away from one another in said third direction by said predetermined layer thickness after each preceding layer has been formed, and with the dispensing of each successive layer being controlled to take place after said mixture in the preceding layer immediately adjacent said dispensing apparatus has solidified.

15. A process as claimed in claim 1, further comprising the steps of:

creating an image of said three-dimensional article on a computer, said image including a plurality of segments defining said article;

generating programmed signals corresponding to each of said segments in a predetermined sequence; and

moving said dispensing apparatus and said build platform relative to one another in response to said programmed signals.

16. A process as claimed in claim 1, wherein said binder removal step removes a major portion of said binder from said article.

17. A process as claimed in claim 1, wherein said binder removal step includes the steps of heating said article to a selected temperature according to a predetermined heating cycle.

18. A process as claimed in claim 17, wherein said binder removal step further includes the step of embedding said article in a powder material prior to said heating step.

19. A process as claimed in claim 17, further comprising the step of heating said article to a temperature greater than said selected temperature to at least partially bond said particulate composition together.

20. A process as claimed in claim 1, further comprising the step of at least partially densifying said article.

21. A process as claimed in claim 20, wherein said densification step includes the step of heating said article to a predetermined temperature to at least partially bond said particulate composition together.

22. A process as claimed in claim 1, further comprising the step of subjecting said article to a pressing step prior to said step of removing at least a portion of said binder.

23. A process as claimed in claim 1, wherein said moving step includes the step of moving said dispensing apparatus and said build platform relative to one another in a direction parallel to said plane according to a first predetermined pattern to form an outer boundary of said mixture on said build platform, said outer boundary defining an exterior surface of said article.

24. A process as claimed in claim 23, wherein said outer boundary defines an interior space in said article, and said moving step further includes the step of moving said dispensing apparatus and said build platform relative to one another in said direction parallel to said plane according to at least one other predetermined pattern to fill said interior space with said mixture.

25. A process as claimed in claim 24, further comprising the steps of creating an image of said

three-dimensional article on a computer, said image including a plurality of segments defining said article, and

generating program signals corresponding to each of said segments in a predetermined sequence, wherein said program signals determine said movement of said dispensing apparatus and said build platform relative to one another in said first predetermined pattern and said at least one other predetermined pattern.

26. A process as claimed in claim 25, wherein said at least one other predetermined pattern includes a plurality of raster segments contacting said outer boundary at points of intersection, and said step of generating program signals includes the step of generating additional program signals to dispense an additional amount of said mixture at said points of intersection.

27. A process for making a three-dimensional article, comprising in the steps of:

creating an image of said three-dimensional article on a computer, said image including a plurality of segments defining said article;

generating program signals corresponding to each of said segments in a predetermined sequence;

providing a mixture of a particulate composition dispersed in a binder;

feeding said mixture to a dispensing apparatus;

dispensing said mixture in a flowable fluid state from said dispensing apparatus onto a build platform;

during said dispensing step, moving said dispensing apparatus and said build platform in response to said programmed signals relative to one another in a plane defined by first and second directions and in a third direction orthogonal to said plane in a predetermined sequence of movements such that said mixture is dispensed in free space as a plurality of segments sequentially formed so that the last dispensed segment overlies at least a portion of the preceding segment in contact therewith to thereby form said three-dimensional article; and

removing at least a portion of said binder from said article.

28. A process as claimed in claim 27, further comprising the step of at least partially densifying said article.

29. A process for making a three-dimensional article, comprising the steps of:

providing a mixture of a particulate composition dispersed in a binder;

feeding said mixture to a dispensing apparatus;

dispensing said mixture from said dispensing apparatus onto a build platform;

during said dispensing step, moving said dispensing apparatus and said build platform relative to one another in a plane defined by first and second directions and in a third direction orthogonal to

said plane to form said mixture into a three-dimensional article;

removing at least a portion of said binder from said article by heating said article to a first temperature according to a predetermined heating cycle; and

heating said article to a second temperature greater than said first temperature to at least partially bond said particulate composition together.

30. A process for making a three-dimensional article, comprising of steps of:

providing a first mixture of one particulate composition dispersed in a binder;

providing a second mixture of another particulate composition dispersed in a binder, said second mixture being different than said first mixture;

feeding said first and second mixtures to a least one dispensing apparatus;

dispensing said first and second mixtures from said at least one dispensing apparatus onto a build platform;

during said dispensing step, moving said at least one dispensing apparatus and said build platform relative to one another in a plane defined by first and second directions and in a third direction orthogonal to said plane to form said first and second mixtures into a three-dimensional article, wherein said first and second mixtures are dispensed in preselected regions of said article; and

removing at least a portion of said binder from said article.

31. A process as claimed in claim 30, wherein said moving step includes the steps of moving said at least one dispensing apparatus and said build platform relative to one another in a direction parallel to said plane according to a first predetermined pattern while dispensing said first mixture to form an outer boundary of said first mixture on said build platform, said outer boundary defining an interior space, and moving said at least one dispensing apparatus and said build platform relative to one another in said direction parallel to said plane according to at least one other predetermined pattern while dispensing said second mixture to fill said interior space with said second mixture.

32. A process as claimed in claim 30, wherein said moving step includes the steps of moving said at least one dispensing apparatus and said build platform relative to one another in a direction parallel to said plane while dispensing said first mixture to form a first layer of said first mixture on said build platform, moving said at least one dispensing apparatus and said build platform away from one another in said third direction by a predetermined layer thickness, and moving said at least one dispensing apparatus and said build platform relative to one another in said direction parallel to said plane while dispensing said second mixture to form a layer of said second mixture on said first layer.

33. A process as claimed in claim 30, wherein said moving step includes the steps of moving said at least one dispensing apparatus and said build platform relative to one another in a direction parallel to said plane while simultaneously dispensing said first and second mixtures to form a layer of said first and second mixtures on said build platform, selected portions of said layer consisting essentially of said first mixture and remaining portions of said first layer consisting

essentially of said second mixture.

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L7: Entry 1 of 2 File: USPT Feb 8, 2000

US-PAT-NO: 6022207
DOCUMENT-IDENTIFIER: US 6022207 A

TITLE: Rapid prototyping system with filament supply spool monitoring

DATE-ISSUED: February 8, 2000

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
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Nelson; Bernard C.	Bloomington	MN		
Docken; Kevin D.	Eden Prairie	MN		

US-CL-CURRENT: 425/145; 242/563.2, 264/308, 425/162, 425/169, 425/375

CLAIMS:

We claim:

1. A rapid prototyping system for making a three-dimensional physical object by depositing solidifiable material in multiple layers, comprising:

a movable extrusion head having an inlet for receiving a filament of a material which solidifies at a predetermined temperature, and an outlet for delivering the material in a molten state;

a spool carrying a coil of filament, the spool having an associated circuit for maintaining data regarding type and amount of filament on the spool;

a filament drive for withdrawing filament from the spool and supplying the filament to the liquifier; and

updating means for updating the data regarding the amount of filament on the spool as a function of filament withdrawn from the spool by the filament drive.

2. The rapid prototyping system of claim 1 and further comprising:

control means for controlling operation of the extrusion head and the filament drive.

3. The rapid prototyping system of claim 2 wherein the control means includes:

means for inhibiting operation of the filament drive and the extrusion head when the amount of filament on the spool reaches a predetermined minimum value.

4. The rapid prototyping system of claim 2 wherein the control means includes:

means for providing an operator notification if the type of filament on the spool does not match a type of material identified by object specification data.

5. The rapid prototyping system of claim 2 wherein the control means includes:

means for providing an operator notification before the start of a job if the amount of filament on the spool is insufficient to create a desired object.

6. The rapid prototyping system of claim 2 wherein the control means includes:

means for providing an operator notification if the filament spool will need replacement during the process of creating a desired object.

7. The rapid prototyping system of claim 1 wherein:

the updating means is encrypted so that the data regarding the amount of filament on the spool can be updated only by a sensing means.

8. A material carrier for use in a rapid prototyping system of the type having an extrusion head having an inlet for receiving a filament of a material which solidifies at a predetermined temperature, and an outlet for delivering the material in a molten state, the material carrier comprising:

a spool on which the filament is wound;

a circuit carried by the spool for maintaining data regarding the type and amount of filament on the spool; and

contacts for providing electrical connection between the circuit and the rapid prototyping system.

9. The material carrier of claim 8 wherein:

the circuit maintains a count representative of the amount of material on the spool.

10. The material carrier of claim 9 wherein:

the circuit updates the count as filament is withdrawn from the spool.

11. The material carrier of claims 8, 9 or 10 wherein:

the circuit is positioned within a sleeve that extends through the center of the spool.

12. The material carrier of claim 11 wherein:

the sleeve has a flange at either end thereof.

13. The material carrier of claim 12 wherein:

one flange is removable to allow withdrawal of the sleeve from the spool.

14. The material carrier of claim 13 wherein:

the flange opposite the removable flange is fixed.

15. A filament spool for use in a rapid prototyping system of the type having an extrusion head having an inlet for receiving a filament of a material which solidifies at a predetermined temperature, and an outlet for delivering the material in a molten state, the filament spool comprising:

a center barrel on which filament may be would;

a sleeve within the barrel for receiving a spindle; and

a circuit board mounted inside the sleeve, the circuit board carrying an electronically readable and writeable device for maintaining data regarding the type and amount of filament on the spool and a set of electrical contacts for receiving a set of mating connector pins connected to the system.

16. The filament spool of claim 15 wherein:

the sleeve has a flange at either end thereof.

17. The filament spool of claim 16 wherein:

one flange is removable to allow withdrawal of the sleeve from the barrel.

18. The filament spool of claim 17 wherein:

the flange opposite the removable flange is fixed.

19. The rapid prototyping system of claim 18 wherein:

the circuit board is mounted adjacent the fixed flange and perpendicular to the barrel.

First Hit Fwd Refs

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L8: Entry 1 of 2 File: USPT Jun 9, 1998

US-PAT-NO: 5764521
DOCUMENT-IDENTIFIER: US 5764521 A

TITLE: Method and apparatus for solid prototyping

DATE-ISSUED: June 9, 1998

INVENTOR-INFORMATION:

NAME	CITY	STATE	ZIP CODE	COUNTRY
Batchelder; John Samuel	Somers	NY		
Jackson; Robert R.	Millbrook	NY		

US-CL-CURRENT: 700/196; 156/244.21, 156/312, 156/350, 264/171.11, 264/171.18, 264/211.21, 264/211.23, 264/328.13, 264/40.7, 425/145, 425/149, 425/375, 700/118, 700/119, 700/182, 700/197, 700/203

CLAIMS:

We claim:

1. Apparatus for making a three-dimensional physical object by sequentially depositing, in a pattern, multiple layers of a solidifiable material on a support member, said apparatus comprising:

nozzle means for providing an extruded material;

pump means having an input and an output, said output in fluid communication with said nozzle means and providing a pressurized flow of said solidifiable material in a fluid state to said nozzle means;

motive means coupled to said pump means for enabling said pump means to provide a variable level of pressurization and rate of flow of said solidifiable material to said nozzle means; and

a pressurization stage having an outlet coupled to said inlet of said pump means, for providing to said inlet said solidifiable material in a fluid state and at a determined pressure which assures, for all operational levels of pressurization and rates of flow in said pump means, that a continuous quantity of said solidifiable material is available at said inlet for continuous operation of said pump means, assuring an uninterrupted flow of said solidifiable material to and through said nozzle means, said solidifiable material supplied to said pressurization stage as a solid, said pressurization stage including:

a conduit for receiving said solid and for applying heat thereto to convert said solid to a fluid state of said solidifiable material; and

drive means for physically impelling said solid into said conduit so as to pressurize said fluid state

of said solidifiable material to said determined pressure.

2. The apparatus as recited in claim 1, wherein said solid solidifiable material is supplied to said drive means in said pressurization stage as a series of solid wafers.

3. The apparatus as recited in claim 2, wherein each said wafer is provided with a formed nonplanar leading surface and a formed nonplanar following surface, said leading surface of a wafer formed to nest with a following surface of a next wafer.

4. The apparatus as recited in claim 2, wherein said drive means comprises:

first and second belt drives disposed in opposition about a feed path, for receiving said wafers between belts of said belt drives and imparting a driving motion thereto.

5. The apparatus a recited in claim 2, further comprising:

removable cassette means for holding a plurality of said wafers;

a holder juxtaposed to said drive means for receiving a cassette means; and

means for removing individual wafers from said cassette means and for causing said wafers to enter said drive means.

6. The apparatus as recited in claim 5, wherein each said cassette means includes an electronically readable data store, said holder including connector means for coupling to said data store upon an insertion of a cassette into said holder, whereby data in said data store is made available to an exterior controller.

7. The apparatus as recited in claim 1, wherein said pump means is a viscosity pump comprising a rotary impeller connected to said motive means, and a mating collet surrounding said impeller, said mating collet coupled to said nozzle means.

8. The apparatus as recited in claim 1, further comprising:

a removable substrate for receiving said solidifiable material from said nozzle means;

a platen for supporting said removable substrate;

means for causing relative movement between said platen and said nozzle means to enable controlled deposition of said solidifiable material on said substrate; and

means for adhering said substrate to said platen.

9. The apparatus as recited in claim 8, wherein said removable substrate comprises a support and an adhesive coating for receiving said solidifiable material, said adhesive coating having a melting point temperature that is lower than a melting point temperature of said solidifiable material, whereby deposition of fluid state solidifiable material causes a melting of an underlying area of said adhesive coating and a hardening thereof occurs as said solidifiable material solidifies.

10. The apparatus as recited in claim 9, wherein said support is a sheet of a magnetic material and said platen includes magnetic means for attracting said magnetic material.

11. The apparatus as recited in claim 8, wherein said platen includes at least one magnetic sensor and said nozzle means is comprised of a magnetic material, said magnetic sensor providing a signal to a controller for enabling control of said means for causing relative movement.

12. An apparatus for providing wafers of solidifiable material to an extruder, comprising:

removable cassette means for holding a plurality of said wafers;

a holder for receiving a cassette means; and

means for removing individual wafers from said cassette means and for causing said wafers to pass to said extruder.

13. The apparatus as recited in claim 12, wherein each said cassette means includes an electronically readable data store, said holder including connector means for coupling to said data store upon an insertion of a cassette into said holder, whereby data in said data store is made available to an exterior controller of said extruder.

14. The apparatus as recited in claim 12, wherein each said wafer is provided with a formed nonplanar leading surface and a formed nonplanar following surface, said leading surface of a wafer formed to nest with a following surface of a next wafer.

15. The apparatus as recited in claim 12, wherein said extruder includes a pressurizing drive means for receiving said wafers from said cassette and comprises:

first and second belt drives disposed in opposition about a feed path, for receiving said wafers between belts of said belt drives and imparting a driving motion thereto which forces said wafers into a fluidizing conduit of said extruder.

16. A method for making a three-dimensional physical object by sequentially depositing, in a pattern, multiple layers of a solidifiable material on a support member, said method employing apparatus which includes a nozzle means for providing an extruded material, pump means having an input and an output, said output in fluid communication with said nozzle means and providing a pressurized flow of said solidifiable material in a fluid state to said nozzle means, motive means for enabling said pump means to provide a variable level of pressurization and rate of flow of said solidifiable material to said nozzle means and a pressurization stage having an outlet coupled to said inlet of said pump means, for providing to said inlet said solidifiable material in a fluid state, said method comprising the steps of:

controlling said motive means to cause said pump means to provide a continuous flow of said solidifiable material to said nozzle means; and

feeding a solid form of said solidifiable material to said pressurization stage at a rate and with an amount of force which assures that a determined pressure is created in said pressurization means which further assures, for all operational levels of pressurization and rates of flow created by operation of said pump means, that a continuous quantity of said solidifiable material is available

at said inlet for continuous operation of said pump means, thereby assuring an uninterrupted flow of said solidifiable material to and through said nozzle means.

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